METHODS OF IRRIGATION

CHAPTER 1

Definition of Irrigation

Irrigation may be defined as the science of artificial application of water to the land, in accordance with the 'crop requirements' throughout the 'crop period' for full-fledged nourishment of the crops.

Following are the factors which govern the importance of irrigation

- Insufficient rainfall
- Uneven distribution of rainfall
- Improvement of perennial crops
- Development of agriculture in desert area

Advantages of irrigation

- Increase in food production
- Optimum benefits
- Elimination of mixed cropping
- Improvement of cash crops
- Source of revenue
- General prosperity
- Generation of hydroelectric power
- Domestic water supply
- Facilities of communications
- Inland navigation
- Afforestation

Disadvantages of irrigation

- Rising of water table: water-logging
- Problem of water pollution (nitrates seepage into GW)
- Formation of marshy land
- Dampness in weather
- Loss of valuable lands

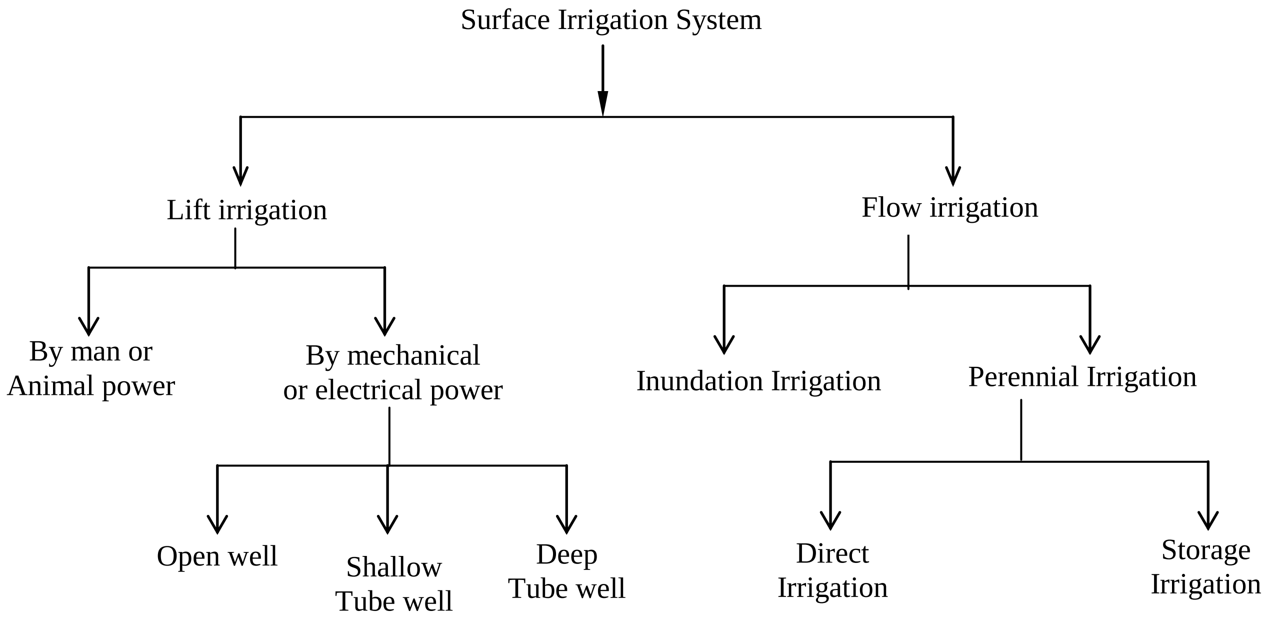
Types of Irrigation

- Surface Irrigation
- Sub-surface irrigation

Surface irrigation

In the surface methods of irrigation, water is applied directly to the soil surface from a channel located at the upper reach of the field. Water may be distributed to the crops in border strips, check basins or furrows. Two general requirements of prime importance to obtain high efficiency in surface methods of irrigation are: distribution systems to provide adequate control of water to the fields and proper land preparation to permit uniform distribution of water over the field. They are also designed to minimize labor and capital requirements. Effective management practices are dependent on the type of irrigation, and the climate and topography of the region.

System of Irrigation



Subsurface irrigation

In sub-irrigation, water is applied below the ground surface by maintaining an artificial water table at some depth, depending upon the soil texture and the depth of the plant roots. Water reaches the plant roots through capillarity action. Water may be introduced through open ditches or underground through pipelines such as drains or mole drains. The depths of open ditches or trenches vary from 30 cm to 100 cm and they are spaced about 15 m to 30 m apart. The water application system consists of field supply channels, ditches or trenches suitably spaced to cover the field adequately and drainage ditches for the disposal of excess water.

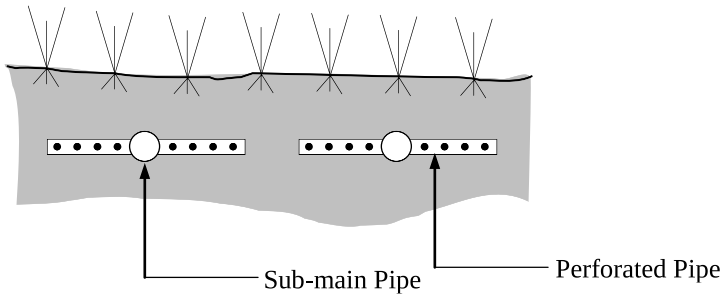
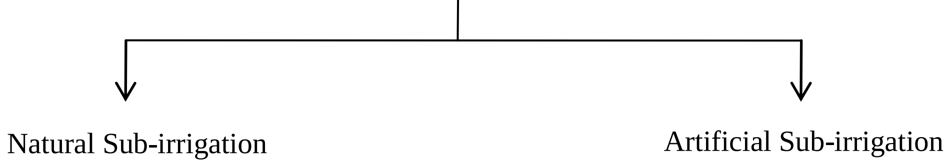


Fig: Sub-surface Method

Sub-Surface Irrigation System



Methods of Irrigation

- Free Flooding
- Border Flooding
- Check Flooding
- Basin Flooding
- Furrow irrigation method
- Sprinkler irrigation method
- Drip irrigation method

Free Flooding or Ordinary Flooding

- Ditches are excavated in the field
- Water is applied from field ditches without any levee to guide its flow.
- Movement of water is not restricted, it is sometimes called "*wild flooding*"
- It is suitable for close growing crops, pastures etc.
- It is practiced large where irrigation water is abundant and inexpensive.
- It involves low initial cost of land preparation, extra labour cost in the application of water.
- Application of efficiency is low.
- This method may be used on rolling land (topography irregular) where borders, checks, basins and furrows are not feasible.

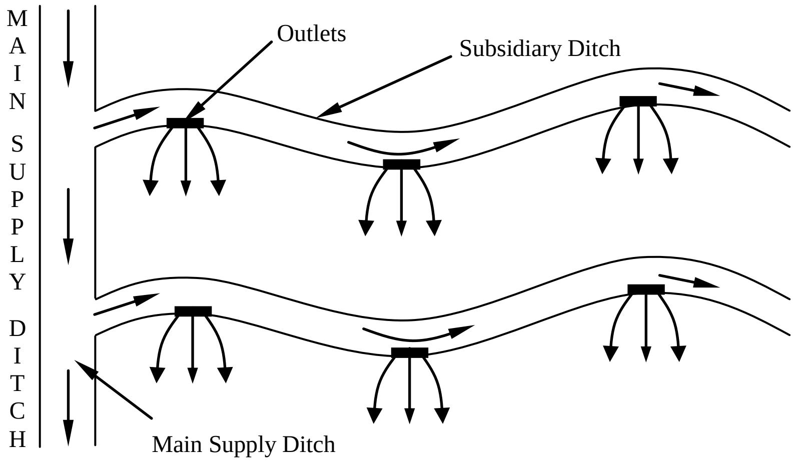


Fig: Free flooding (plan view)

Border Flooding

- The farm is divided into a number of strips (width 10 ~ 20 m and length 100 ~ 400 m) separated by low levees or borders.
- Water is turned from the supply ditch into these strips along which a flow slowly toward the lower end, wetting the soil as it advances. When the advancing water front reaches the lower end, the stream turned off.
- The surface is essentially level between levees and lengthwise slope is somewhat according to natural slope of the land (0.2 ~ 0.4%)
- It is suitable to soils having moderately low to moderately high infiltration rates and to all closely growing crops.
- Uniform distribution and high water application efficiencies are possible.
- Large streams can be used efficiently.
- It involves high initial cost.
- Ridges between borders should be sufficiently high
- The land should be perpendicular to the flow to prevent water from concentrating on either side of the border

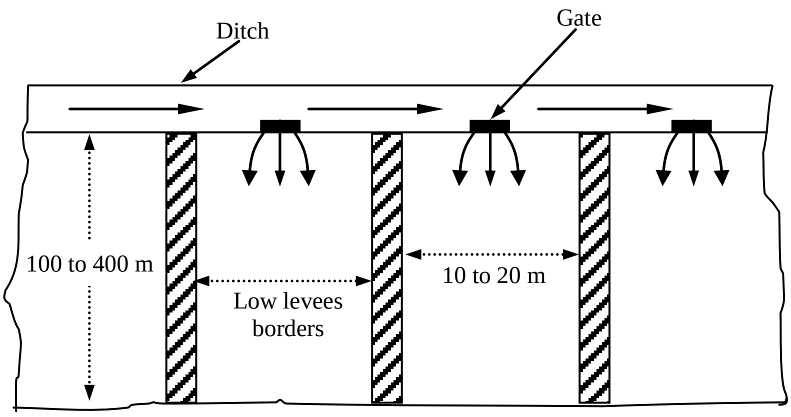


Fig: Border flooding (Plan view)

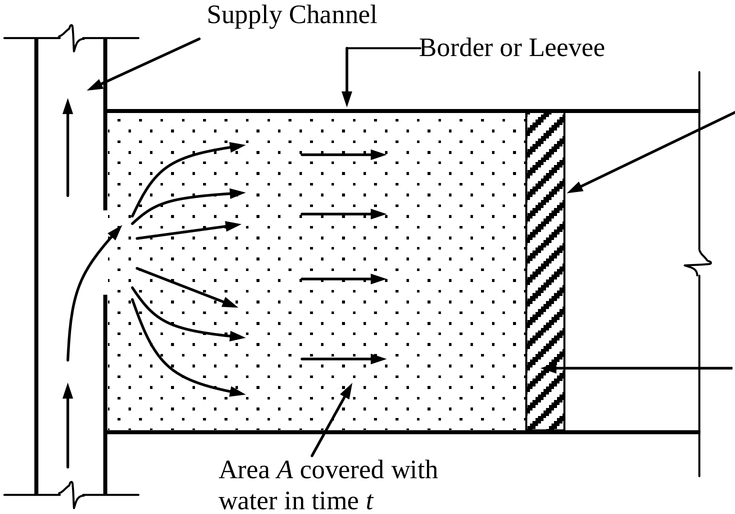
Determination of required time to irrigate in border flooding

A relationship between the discharge through the supply ditch (Q), the average depth of water flowing over the strip (y), the rate of infiltration of the soil (f), the area of the land irrigated (A), and the approximate time required to cover the given area with water (t), is given by the equation:

$$t = 2.3\frac{y}{f}\log\left(\frac{Q}{Q - fA}\right)$$

Where, Q = Discharge through the supply ditch
y = Depth of water flowing over the border strip
f = Rate of infiltration of soil
A = Area of land strip to be irrigated
t = Time required to cover the given area A

Derivation of Equation: $t = 2.3\frac{y}{f}\log\left(\frac{Q}{Q - fA}\right)$



Considering small area, dA of the border strip of area (A)

Depth of water, y over this area (A)
Assume that in time dt, water advances over this area (dA).
Now, the volume of water that flows to cover this area = y.dA ------------------------ (1)

During the same time dt

The volume of water that percolates into the soil over the area (A) = $f.A.dt$ --------------- (2)
The total quantity of water supplied to the strip during time (dt) = $Q.dt$ ------------------- (3)

From equation (1), (2) & (3) $\Rightarrow$

$\therefore$ Q .dt = y. dA + f. A. dt

$$\Rightarrow dt = \left(\frac{y.dA}{Q - f.A}\right)$$

For getting time required to irrigate the whole land, we have to integrate the above equation and considering y, f, and Q as constants

$$\int dt = \int\left(\frac{y.dA}{Q - f.A}\right)$$

After integrating the above equation, we get

$$t = \frac{y}{f}\ln\left(\frac{Q}{Q-f.A}\right) + C \text{ (constant)} \text{ ------------------------------------- (4)}$$

But at, t = 0, A = 0

From equation (4) $\Rightarrow$

$$0 = \frac{y}{f}\ln\left(\frac{Q}{Q-f.0}\right) + C$$

$$0 = \frac{y}{f}\ln\left(\frac{Q}{Q}\right) + C = \frac{y}{f}\ln(1) + C = \frac{y}{f}\times 0 + C = 0 + C \quad \therefore C = 0$$

Finally, $\therefore$ $t = \frac{y}{f}\ln\left(\frac{Q}{Q-fA}\right)$

or, $$\boxed{t = 2.3\frac{y}{f}\log\left(\frac{Q}{Q-fA}\right)}$$

This above equation can be further written as

$$\frac{t.f}{2.3.y} = \log\left(\frac{Q}{Q-fA}\right) \qquad \text{Now, let } \frac{t.f}{2.3.y} = x$$

Then, $x = \log\left(\frac{Q}{Q-fA}\right) \Rightarrow 10^x = \left(\frac{Q}{Q-fA}\right)$

$\Rightarrow Q.10^x - f.A.10^x = Q$

$\Rightarrow Q(10^x - 1) = f.A.10^x$

$\Rightarrow A = \frac{Q(10^x - 1)}{f.10^x}$

Further, considering the maximum value of $\frac{10^x - 1}{10^x} = 1$

We get, $$\boxed{A_{max} = \frac{Q}{f}}$$

Problem:

Determine the time required to irrigate a strip of land of 0.04 hectares in area from a tube-well with a discharge of 0.02 cumec. The infiltration capacity of the soil may be taken as 5 cm/h and the average depth of flow on the field as 10 cm. Also determine the maximum area that can be irrigated from this tube well.

***Solution*:**

Here, $A = 0.04$ hectares $= 0.04 \times 10^4\ m^2 = 400\ m^2$

$Q = 0.02$ cumec $= 0.02\ m^3/s = 0.02 \times 60 \times 60\ m^3/hr = 72\ m^3/hr$

$f = 5$ cm/hr $= 0.05$ m/hr

$y = 10$ cm $= 0.10$ m

Now,

Time required for irrigating the strip of land, $t = 2.3\frac{y}{f}\log\left(\frac{Q}{Q-fA}\right)$

$$= 2.3\times\frac{0.10}{0.05}\times\log\left(\frac{72}{72-0.05\times 400}\right) = 0.65 \text{ hr} = 39 \text{ min}$$

Maximum area that can be irrigated is given by the equation:

$$A_{max} = \frac{72}{0.05}\ m^2 = 1440\ m^2 = 1440/10^4 \text{ hectares} = 0.144 \text{ hectares}$$

Check Flooding

- Similar to Ordinary flooding
- Water is controlled by surrounding the ***check*** area with low and flat levees
- The check is filled with water at a fairly high rate and allowed to stand until the water infiltrates
- The confined plot area varies from 0.2 to 0.8 hectares

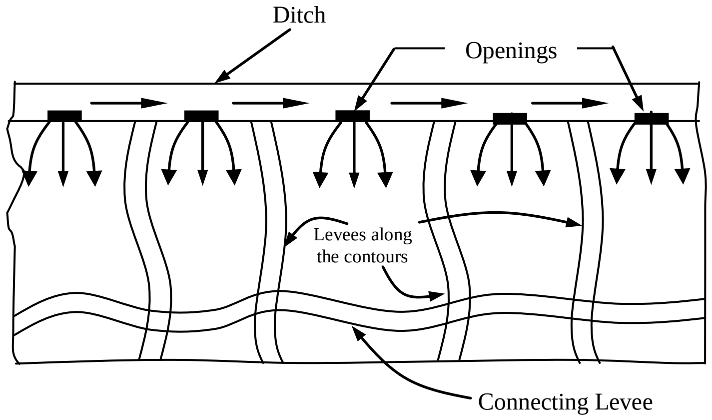


Fig: Check flooding (Plan view)

***Adaptability*:**

- It is suitable for low as well as high intake soils and for rice or other crops which can withstand temporary flooding.

***Advantages*:**

- Effective leaching.
- Maximum use of seasonal rainfall
- High application efficiencies.

***Limitations*:**

- Soil crusting
- Unsuitable for crops that cannot accommodate inundation.

Basin Flooding

- Special type of check flooding
- Adopted specially for "Orchard trees"
- One or more trees are generally placed in the basin
- Surface is flooded as in check method by ditch water

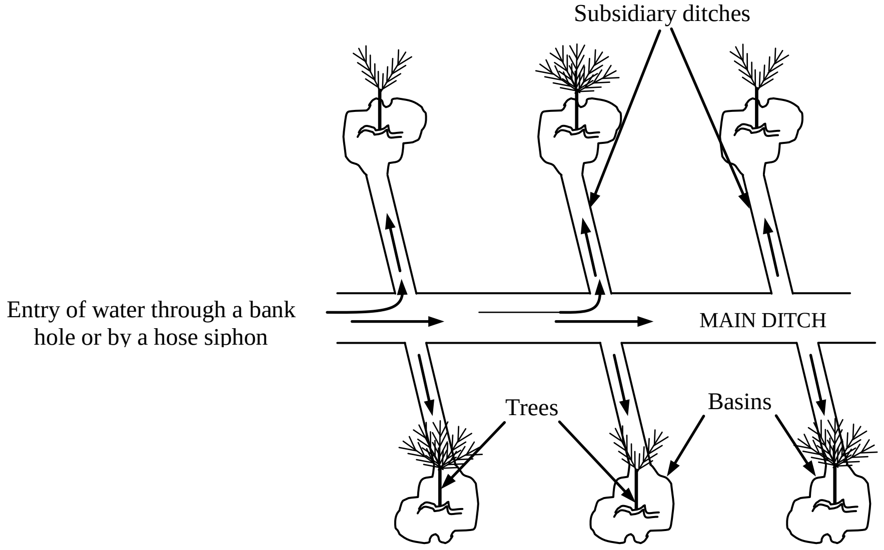


Fig: Basin Flooding (plan view)

***Adaptability*:**

- It is suitable for low as well as high intake soils.

***Advantages*:**

- Effective leaching
- Maximum use of seasonal rainfall
- High application efficiencies

***Limitations*:**

- Soil crusting
- Unsuitable for crops that cannot accommodate inundation.
- Application efficiency is comparatively high.

<u>Furrow irrigation method</u>

- Furrow are narrow field ditches, excavated between rows of plants and carry water through them
- Spacing of furrows is determined by proper spacing of the plants.
- Furrows vary from 8 to 30 cm deep and may be as much as 400 meters long
- Deep furrows are widely used for row crops.
- Small shallow furrow (***called corrugations***) suitable for irregular topography and close growing crops such as meadows and small grains.
- Water diverted into the furrows by using *rubber hose tubing*.
- Hose prevents the necessity of breaking of the ditch bank and provides a uniform flow into the furrow.

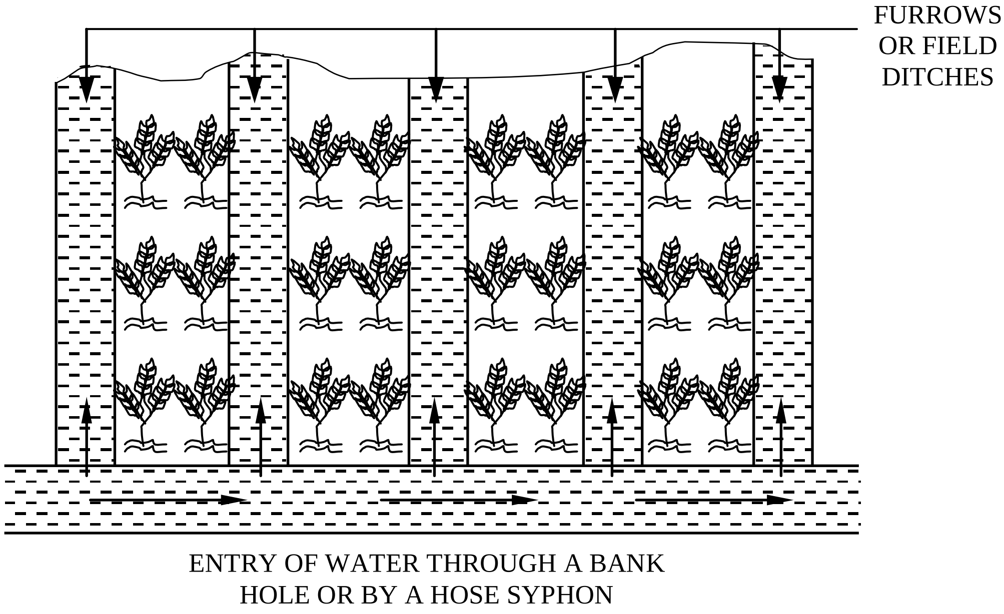


Fig: Plan view (Furrow irrigation method)

***Adaptability*:**

It is suitable for row crops (like potatoes, groundnut, sugarcane etc.) and for medium to moderately fine textured soil.

***Advantage*:**

Only about one-fifth to one-half of the land surface is wetted by water. So, it results in less evaporation, less pudding of soil.

***Disadvantages*:**

- Excessively long furrows may result in too much percolation near upper end and too little water near the down-slope end.
- It involves high initial cost and salt accumulation in the ridges.

<u>Sprinkler irrigation method</u>

- Water is applied to the soil in the form of a spray through a network of pipes and pumps.
- It is kind of an artificial rain and gives good results
- It is a costly process and not widely used in our country.
- It can be used for all types of soils and for widely different topographies and slopes.
- It fulfills the normal requirement of uniform distribution of water.

***Adaptability*:**

- This method can be used for almost all crops (except rice and jute) and on most soils.
- It is best suited to sandy soils that have a high infiltration rate.
- It can be applied to any topographic conditions without extensive land preparation.

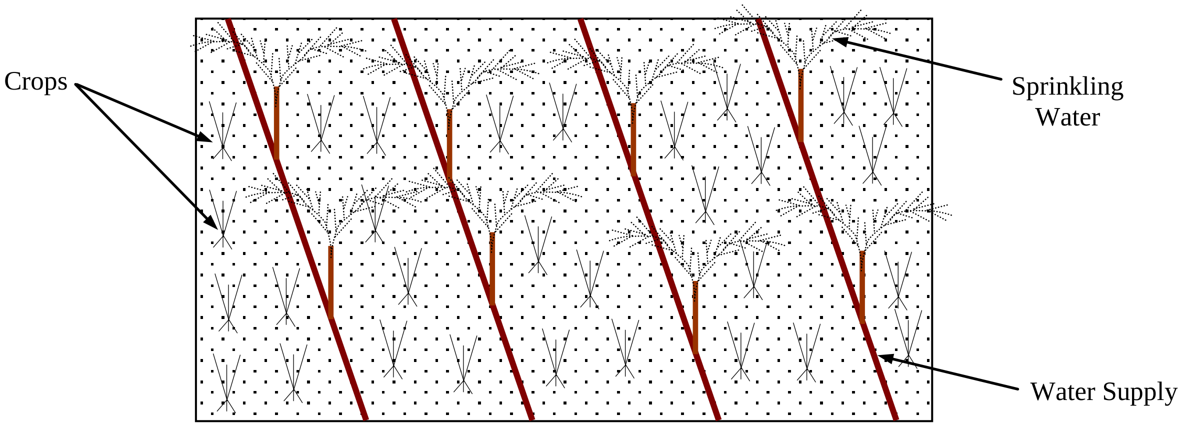


Fig: Plan view (sprinkler irrigation method)

Types of sprinkler systems:

- <u>Permanent system</u>: In permanent system, pipes are permanently buried in such a way that they do not interfere with the farming operations.
- <u>Semi-permanent system</u>: In semi-permanent system, the main lines are buried in the ground, while the laterals are portable.
- <u>Portable system</u>: In the portable system, the mains as well as laterals are portable. These portable networks can be moved from farm to farm

Advantages of sprinkler irrigation:

- Seepage losses, which occur in earthen channels of surface irrigation methods, are completely eliminated. Moreover, only optimum quantity of water is used in this method
- Land leveling is not required and thus avoiding removal of top fertile soil, as happens in other surface irrigation methods.
- No cultivation area is lost for making ditches results in increasing about 16 % of the cropped area
- The water is to be applied at a rate lesser than the infiltration capacity of the soil, and thus avoiding surface run off.
- This method leaches down salts and prevents water-logging or salinity
- It is less labor oriented and hence useful where labor is costly and scarce.
- Up to 80% of applied water can be stored in the root zone of plants.
- Fertilizers can be uniformly applied, because they can mixed with irrigation water

Limitations of sprinkler irrigation:

- High winds may distort sprinkler pattern, causing non-uniform spreading of water on the crops.
- In areas of high temperature and high wind velocity, considerable evaporation losses of water my take place.
- They are not suited to crops requiring frequent and larger depths of irrigation, such paddy.
- Initial cost of the system is very high, and the system requires a high technical skill
- A constant water supply is needed for commercial use of equipment
- Only sand and silt free water can be used, as otherwise pump impellers lifting such waters will get damaged.

Drip irrigation method

- It is the latest field irrigation technique (also called **trickle** irrigation)
- Irrigation water is applied by using small diameter (12 to 32 mm) plastic lateral lines.
- The lateral lines contains some devices called 'emitters' at selected spacing to deliver water to the soil surface near the base of the plants.
- It is best suited for widely spaced plants, salt problems and for areas with water scarcity.
- In this method, water is slowly and directly applied to the root zone of the plants for minimizing the losses by evaporation and percolation
- This method is being used for small nourishes, orchards, or gardens.

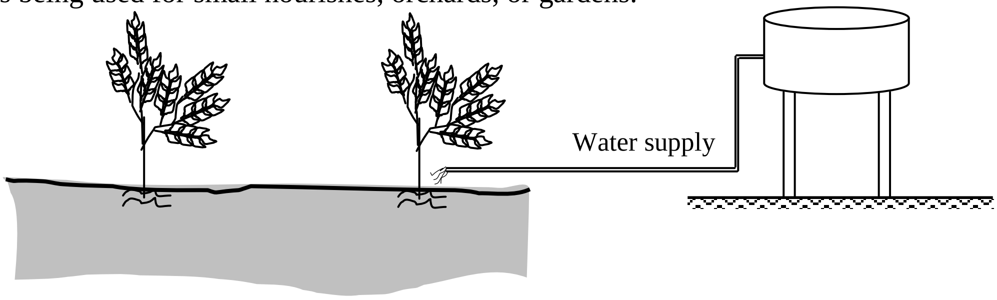


Fig: Section view (Drip irrigation method)

***Benefits*:**

- Conventional losses such as deep percolation, runoff and soil water can be minimized by applying a volume of water approaching the consumptive use of the plants.
- Small area is wetted thereby reducing weed growth, insects and diseases etc.
- Soil crusting and interference with harvesting is minimized.
- Greater crop yield and better quality can be obtained.
- For widely spaced like fruit trees, the system may be even more economical than sprinkler method of irrigation.

***Disadvantages*:**

- High initial cost of the deep irrigation equipment sometimes limits its use to orchard and vegetables in water scarcity areas.
- Clogging of emitter may disrupt the irrigation system.
- Plastic pipes may damaged by rodents.
- Wind erosion can harm the pipes.
- Like the sprinkler method, drip irrigation permits the simultaneous application of fertilizers through the system.
- When compared to the sprinkler system, the drip method operates on much lower line pressure, thus providing a saving in energy requirements.

Irrigation Project Surveying

- **Availability of Irrigation Water**
  When it is found necessary to take up an irrigation project, the availability of required water should be investigated. The following points should be considered
  - Whether any perennial river is available near the command area or not.
  - If an inundation river is available, the maximum discharge of that river is to be ascertained from the highest flood level mark (as indicated by the villagers residing near the bank of the river).
  - From various investigations (i.e. maximum discharge, rainfall etc.) it is necessary to ascertain whether the river will be able to meet the total water requirement or not.

- **Selection of probable site for Barrage or Dam**
  When the source of water is available, the suitable site for the barrage or dam should be found out considering the following points,
  - The course of the river should be straight at least for a distance of about one kilometer both on the upstream and down-stream side of the site.
  - The width of the river should be minimum and the section of the river should be well-defined.
  - A suitable basin should be available for the storage reservoir.
  - The elevation of the site should be higher than that of the culturable command area.
  - The storage reservoir should not submerge much valuable land.
  - The capacity of the reservoir should fulfill the total water requirement.

- **Discharge observation for the river**
  The gauge and discharge observation station should be established at the proposed site to collect the following data:
  - The daily discharge, maximum discharge and minimum discharge of the river throughout the year should be recorded.
  - Silt analysis should be carried out in rainy season (when the river carries much silt) to determine the nature of sedimentation in river or reservoir.
  - Discharge observations should also be carried out for all the rivers crossing the proposed canal. This is required for designing cross-drainage works.

- **Marking of GCA and Cultivable area**
  When it is decided to make up the project, the gross command area should be marked on the topographic map. The culturable areas should be defined on the map to find the culturable command area that is to be included in the project.

- **Marking of alignment of main canal**
  The alignment should be marked on the topographical map of the concerned area. While marking the alignment the following points should be kept in mind.
  - The alignment of the main canal should be taken in such a way so that unnecessary cutting and banking is avoided.
  - The alignment of the main canal should be such that the branch canals can be taken suitably to cover the whole culturable area.
  - The alignment should cross the rivers, roads, railways lines etc. perpendicularly as much as possible.
  - The alignment should not be taken through the valuable agricultural land.
  - The alignment should not pass through the thickly populated areas, religious places, burial grounds, etc.

- **Preliminary location survey**

  The reconnaissance survey should be carried out along the alignment to record necessary data such as obstacles, road crossings, railway crossings, river crossings, etc. This survey involves the following procedures:

  - The approximate distance along the alignment should be measured by pacing and the magnetic bearings of the traverse legs (open traverse) and it should be noted in the field book.
  - The objects and the nature of the ground on both sides of the alignment should also be noted in the field book.
  - The alignment may be diverted to avoid religious places, valuable structures, etc.
  - The alignment should be made to cross the rivers perpendicularly.
  - An index should be prepared for the alignment.

- **Final Survey:**

  a) ***Final location of Barrage or Dam:*** The final location of the barrage or dam site involves the following steps:

     - The centre line of the barrage or dam site should be marked with pillars on both banks of the river.
     - The cross-section of the barrage site should be taken very precisely.
     - Cross-sections should be taken at regular interval on the upstream side of the barrage site to ascertain the storage capacity of the reservoir.
     - Boring test should be carried out along the centre line of the barrage site to determine the depth and nature of foundation.

  b) ***Route survey:*** A prismatic compass survey or plane table survey should be conducted along the alignment of the main canal to prepare a route survey map of the area covering a distance of about 30 m on both sides of the alignment.

  c) ***Longitudinal leveling:*** The longitudinal leveling should be done along the alignment of the main canal. Generally, the staff readings are taken at an interval of 20 m along the centre line of the main canal. The magnetic bearings of the lines (traverse legs) should also be noted in the level book. Longitudinal leveling for the branch canals should also be done.

  d) ***Cross-sectional leveling:*** The cross-sectional leveling at regular intervals along the alignment of the main canal should be taken. The cross-sections for the branch canals also should be taken. These cross-sections are required for the computation of volume of earth work.

  e) ***Data for cross drainage works:*** At the places of river crossings, road crossings, railway crossings etc. additional data should be collected for designing cross-drainage works. At the sites of river crossings the gauge and discharge observation stations should be established.

  f) ***Soil survey:*** The soil survey should be conducted along the alignment. It consists of collecting the sample of soil by boring up to the depth until impervious layer is obtained.

  g) ***Well observation:*** Well observation should be carried out along the alignment. This operation consists of measuring the water level of the wells existing on both sides (within 50 m) of the alignment. This is done to know the nature of water table along the course of the canal.

Preparation of drawings

- Route survey map (to suitable scale).
- Longitudinal sections for the main and branch canals with formation level (to suitable scale).
- Cross-sections of main and branch canals with formation level (to suitable scale).
- Contour map along the alignment.
- Design of curves with setting out table.

Office works

- The sections of the canals should be designed.
- The detailed estimate should be prepared to know the volume of earth work in cutting or banking along the main canal and branch canals.
- The total land width required should be marked on the route survey map.
- The design of the barrage or dam, cross-drainage works and other allied structures should be completed.
- The detailed report should be prepared for the compensation. It includes the names of owners, location, amount of properties, valuation of the land, etc.
- The total cost of the project should be ascertained by considering all the aspects.

Justification of the selection of final alignment

After preliminary survey, the estimates for the tentative alignments (if taken) are prepared. Then by comparing the total costs, working feasibility, etc. with the alignments the final alignment is selected.

Final location survey

The final location survey of the approved alignment of the canal should be carried out for the execution of the project works. It includes the following:

- The center line of the main and branch canals should be marked with concrete pillars at intervals of 30 m or 50 m.
- The total land width required for the main and branch canals should be marked with pillars at suitable intervals.

Irrigation Project Report

- Introduction: The introduction of the project includes the following points:
  - Aim of the project
  - Location of the project
  - Total area to be covered within the project.
  - Total population to be benefited by the project.
  - Future prospect if irrigation is practiced.
  - Stages of future development.
  - Total cost of the project.

- **Necessity and economic justification**
  To justify the necessary and economical development of the area, the following points should be clearly illustrated:
  - Amount of yearly rainfall.
  - Nature of distribution of rainfall during the crop season.
  - Types of major crops grown in the area.
  - Total water requirement of the crops.
  - Amount of water requirement by irrigation system.
  - Expected increase in yield of crops, if irrigation is practiced.
  - Total revenue expected.

- **Report on land acquisition and compensation**
  A detailed statement should be prepared showing the names of owners, types of properties, quantity, amount of compensation, etc. The procedure adopted for the land acquisition should be clearly mentioned.

- **Details of design and drawing of hydraulic structures**
  The detailed design procedure and drawing of hydraulic structures, canals and other allied structures should be incorporated.

- **Detailed estimate**
  The detailed estimate for all the works of the project should be incorporated.

- **Specification**
  The specifications of the construction materials and different works should be clearly mentioned.

- **Availability of materials and laborers**
  The source of construction materials and places of recruitment of laborers should be mentioned.

- **Communication**
  The existing communication to the selected barrage or dam site should be pointed out. If new communication is required for inaccessible site, the possible route should be pointed out and the expenditure for the new route should be included in the project.

- **Maps**
  - Topographical map of the area showing the canal alignment and barrage or dam site.
  - Route survey map.
  - Longitudinal sections.
  - Cross-sections.
  - Contour map of alignment.
  - Detailed drawing of barrage or dam, cross-drainage works, etc.

- **Conclusion and recommendation**
  After furnishing all the aspects of the project, the proposal is forwarded to the higher authority with proper recommendation for the necessary approval.